

Point-contact spectroscopy of the borocarbide superconductor YNi₂B₂C

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Abstract

Point-contact (PC) spectroscopy measurements on YNi₂B₂C single crystals in the normal and superconducting (SC) state ($T_c \simeq 15.4$ K) for the main crystallographic directions are reported. The PC study reveals the electron-phonon interaction (EPI) function with a dominant maximum around 12 meV and a further weak structure (kink or shallow broad maximum) at higher energy at about 50 meV. Other phonon maxima at 20, 24 and 32 meV specified in the phonon DOS of YNi₂B₂C by neutron measurements [PRB, **55**, 9058 (1997)] are not resolved in the PC spectra pointing out to the main role of the low energy phonon modes in EPI. Directional study of the SC gap results in $\Delta_{[100]} \approx 1.5$ meV for the *a*-direction and $\Delta_{[001]} \approx 2.4$ meV along the *c*-axis which may point to anisotropic and/or multiband behavior. Noteworthy, the critical temperature T_c in all cases corresponds to that of bulk samples. The value $2\Delta_{[001]}/k_B T_c \approx 3.6$ is close to the BCS one of 3.52, and the temperature dependence $\Delta(T)$ is BCS-like, while for the *a*-direction $\Delta(T)$ deviates from mean-field BCS behavior above $T_c/2$. The directional variation in Δ can be attributed to the multiband nature of the SC state in YNi₂B₂C predicted 10 years ago (PRL, **80**, 1730 (1998)).

Key words: YNi₂B₂C, borocarbides, point-contact spectroscopy, superconducting gap, electron-phonon interaction
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By point-contact (PC) researches both the superconducting (SC) gap and the PC electron-phonon interaction (EPI) function $\alpha_{\text{PC}}^2 F(\omega)$ can be determined by measuring the first and second derivatives of the $I(V)$ characteristic of PC's [1]. Thus the PC spectroscopy is a powerful method to study both the EPI spectra and the SC gap behavior.

In the family of borocarbide superconductors YNi₂B₂C is remarkable because of its relative high critical temperature $T_c \simeq 15.4$ K among nonoxide ternary compounds. In particular, the nature of the attractive interaction and the SC order parameter remain challenging. So far several thermodynamic, transport and spectroscopic measurements give a clear evidence for a notable anisotropy of the SC

gap in this compound [2]. Concerning the EPI studies there is not much information available except the PC data cited in [1].

We have measured PC EPI spectra of YNi₂B₂C with a pronounced phonon maxima at about 12 mV and a broad maximum or shoulder around 50 mV (Fig. 1). These peaks correspond to the features seen in the phonon DOS [3], however 20, 24 and 32 mV phonon maxima are not resolved in the PC spectra. We have obtained the PC EPI spectra for different directions and for contacts with different SC gap Δ , which is distributed (see Fig. 2) between 1.5 meV and 2.5 meV, however, no qualitative difference between PC EPI spectra is observed. In all cases, a more or less broad 12 mV-maximum prevails in the

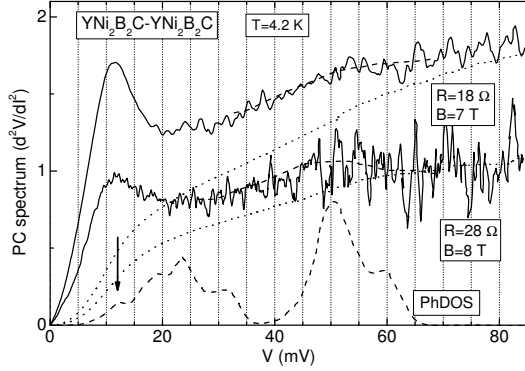


Fig. 1. (a) PC spectra of two $\text{YNi}_2\text{B}_2\text{C}$ homocontacts averaged for two polarities. The superconductivity is suppressed by a magnetic field. Dotted curves show the tentative background behavior. Dashed curves on the PC spectra are a guide for eyes to improve the visualization of the maximum around 50 mV. The bottom curve shows the phonon DOS for $\text{YNi}_2\text{B}_2\text{C}$ [3].

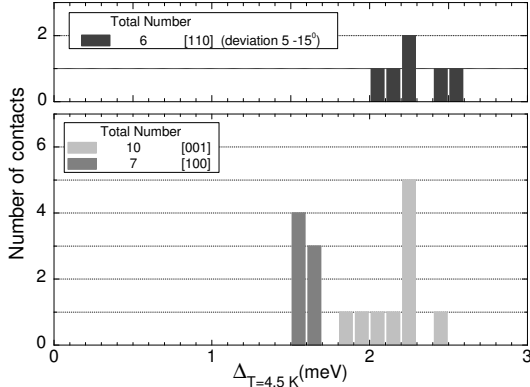


Fig. 2. Gap distribution for the three main directions in $\text{YNi}_2\text{B}_2\text{C}$ single crystal.

PC EPI spectra. This points out the main role of the low energy phonons in EPI which contribution to the EPI constant $\lambda_{\text{PC}} = 2 \int \alpha_{\text{PC}}^2 F(\omega) \omega^{-1} d\omega$ is estimated to about 90%. PC EPI spectra were measured by suppressing of superconductivity by magnetic field or temperature to avoid features in the spectra due to SC gap. In this case we did not found in the PC EPI spectra any "soft" modes at about 5 mV mentioned, e. g., by Martinez-Samper et al. [2].

The SC gap Δ manifests itself in the dV/dI curve of a N-c-S contact as pronounced minima around $V \simeq \pm \Delta$ at $T \ll T_c$. Such dV/dI are presented in

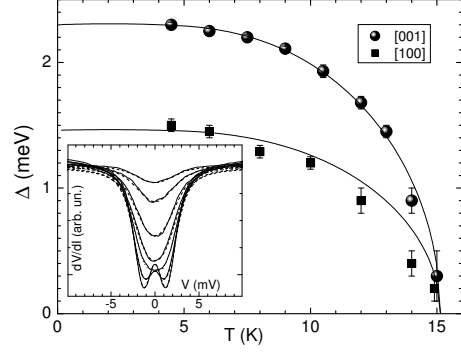


Fig. 3. Temperature dependence of the small and large gap in $\text{YNi}_2\text{B}_2\text{C}$. Solid curves represent BCS-like behavior. Inset shows example of dV/dI curves (solid) for the small gap along with fitting curves (dashed).

Fig. 3(inset). We have measured the gap distribution for the different crystallographic directions in $\text{YNi}_2\text{B}_2\text{C}$ shown in Fig. 2. The anisotropy in the distribution is clearly seen: the small gap is characteristic for the a-axis, while along the c-axis the gap is larger. Also the [110] direction has in average the largest gap. Important is that for many of PCs with different gap we have checked the critical temperature $T_{c,\text{PC}}$, which was always close to the bulk T_c . This avoids the gap variation due to, i. e., the surface degradation.

The SC gap Δ and its temperature dependence are established (Fig. 3) from the fit of dV/dI . It is seen that $\Delta(T)$ has BCS-type dependence, however the small gap deviates from the BCS curve by approaching T_c . Similar (small) gap behavior is characteristic for the multiband superconductor MgB_2 . For borocarbides, multiband superconductivity has been firstly proposed already in 1998 [4].

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